

LASER-ARC PROCESS AND TECHNOLOGY FOR DEPOSITION OF AMORPHOUS AND NANO-STRUCTURED CARBON FILMS

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Abstract

Pulsed-laser (PLD) and vacuum arc deposition techniques (VAD) are successfully applied for thin film synthesis, especially for the preparation of super hard amorphous carbon films (ta-C) and carbon nano-structures. The main advantage of both technologies is that the evaporated material is nearly completely ionized. PLD is a well controlled process, which can be used for the deposition of nearly all materials (conductive and dielectric) with a defined nano-structure, but with a low efficiency. VAD is an industrial used technology for hard coating deposition with high deposition rate and efficiency, but limited in controlling the arc discharge. The stochastically movement of the cathode spots induces macro-particles, which will be included in the deposited films. These particles are the reason for a restricted coating quality by a high surface roughness and defect density. To deposit coatings of a high quality with VAD technologies, the arc discharge has to be better controlled and filter techniques have to be applied for removing macro-particles from the plasma.

LASER-ARC PROCESS

The Laser-Arc process is developed to combine the advantages of PLD and VAD for a controlled deposition of high quality carbon films with a defined nano-structure with a high deposition rate. In the Laser-Arc process the arc discharge is guided on the cathode surface in a highly controlled manner by positioning the igniting laser pulses. The burning time of the arc is limited to 130 μ s by the high current power supply. Using a peak arc current between 1 and 1.8 kA the splitting cathode spots move from the ignition point (the laser spot) driven by intrinsic magnetic fields. The subsequent arc pulse will be ignited at a fresh position of the cathode by moving the laser beam. This way overheating and melting of the cathode surface is prevented and the particle emission is reduced. Efficient deposition rates are obtained at repetition rates of 1 kHz. To coat large areas the cathode roll is 400 mm in length. By linear scanning the laser beam and simultaneously rotating the cylindrical cathode a very regular erosion of the cathode material is achieved (Fig. 1) [1].

For industrial coating application the cathode was arranged in a separate source chamber (Laser-Arc Module/LAM), which can be combined with any conventional industrial used batch coater. The advantage of this LAM concept is that the whole equipment and all functions of the basic coater (e.g. vacuum production, sample planetary, cleaning technology, hard coating deposition and some more) can be used. Additionally, conventional coatings can be overcoated with hard ta-C, nano-structured or modified carbon top films [2].

SUPER HARD AMORPHOUS CARBON FILMS (DIAMOR[®])

The plasma created by the laser controlled high current arc discharge is characterized by nearly complete ionization and high kinetic energies of the ions (e.g. 3- - 50eV for carbon). If the deposition is carried out under high vacuum ($p < 10^{-3}$ Pa) conditions at low substrate temperatures ($T < 150^{\circ}\text{C}$), amorphous carbon films are obtained. Their hardness reaches values between 2,000 and 6,000 HV depending on the deposition parameters. The film micro-structure is dominated by diamond-like bonds (sp^3). Film thicknesses of 10 μm and more with an excellent adhesion to steel are achieved if a special plasma surface treatment and interlayer preparation is applied. But also other substrate materials can be coated successfully, especially Ti and Al alloys or plastics (low thermal load during the coating process). Such films are successfully tested as wear protecting coatings with a low friction coefficient in

tribological friction pairs under high mechanical loads without lubrication. Diamor coated tools are successfully applied for dry machining of Al-alloys [2].

NANO-STRUCTURED CARBON FILMS

If the carbon deposition is performed in a residual inert gas (Ar) atmosphere at pressures up to 4 Pa the film structure is dominated by graphitic bonds (sp^2). The films still exhibit a high hardness of about 4,000 HV and a corresponding Young's Modulus of more than 400 GPa. The reason of the unexpected high hardness of graphitic carbon films was found in the nanostructure by means of a high resolution transmission electron microscopy study. Fullerene-like nano-particles were found to be the reason for the high stiffness and elastic recovery properties of such films. High stiffness is not only typical for diamond but also inside the graphite layers. The easy sliding of these layers is suppressed by the curved and closed geometry of graphite nano-structures [3]. In contrast to more or less non-conducting diamond-like carbon films these nano-structured films are electrically conductive and have a similar wear resistance and low friction.

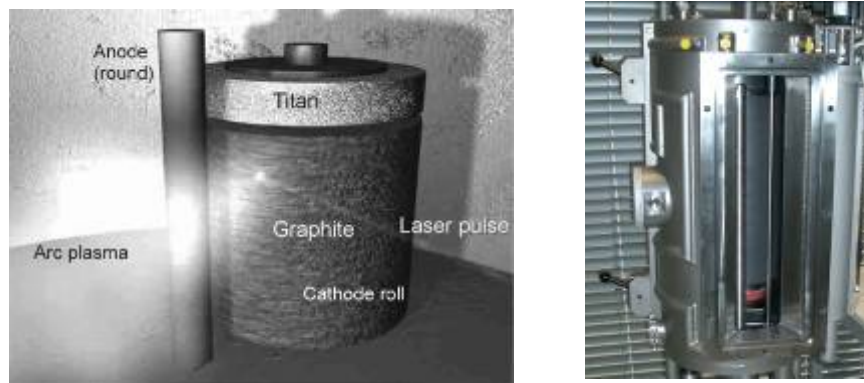


Figure1. Scheme of the Laser-Arc process and industrial used Laser-Arc-Module (LAM).

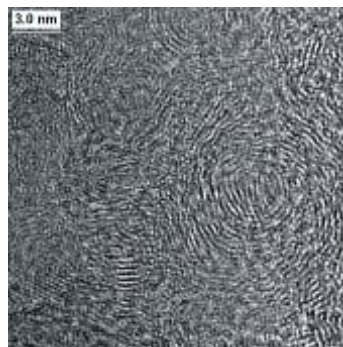


Figure 2. HRTEM image of a nano-structured C-film (top view)

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